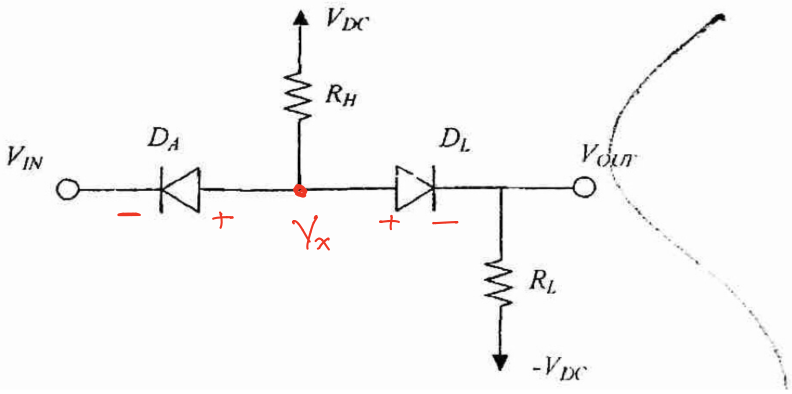
Question 2: [5 Marks]

Sketch the VTC for the diode level-shifting circuit shown below over the range $-V_{DC} \le V_{IN} \le V_{DC}$. Use $V_{DC} = 3V$ and $R_H = R_L = 3K\Omega$. Also let $V_D(ON) = 0.65V$

① D_A ON D_L ON
② D_A off D_L ON
③ D_A ON D_L off
④ D_A off D_L off



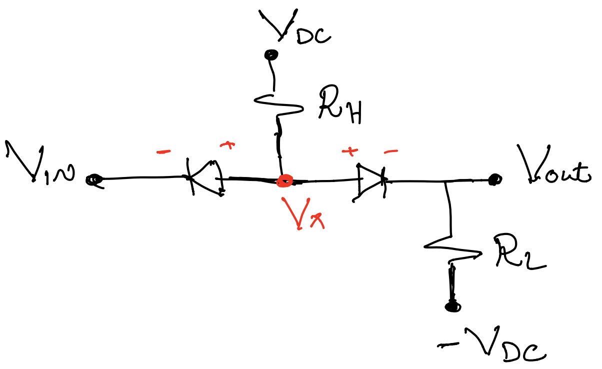
① D_A ON, D_L ON

$$V_{out} = V_x - V_{D(ON)}$$

$$V_x = V_{IN} + V_{D(ON)}$$

$$V_{out} = V_{IN} + V_{D(ON)} - V_{D(ON)}$$

$$\boxed{V_{out} = V_{IN}}$$

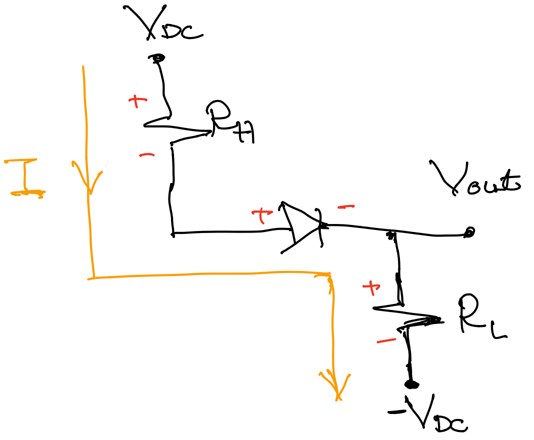


② D_A off, D_L ON

$$V_{out} = IR_L - V_{DC}$$

$$I = \frac{V_{DC} - V_{D(ON)} + V_{DC}}{R_H + R_L}$$

$$= \frac{3 - 0.65 + 3}{(3+3)K} = 891.7\mu A$$



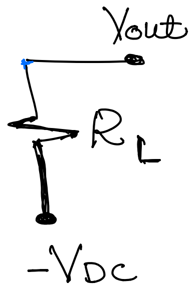
$$V_{out} = 891.7\mu \times 3K - 3 = -0.325V$$

$$\boxed{V_{OH} = -0.325V}$$

∴ at the edge $V_{out} = V_{in}$ is still valid & $-V_{DC} \le V_{IN} \le V_{DC}$

$$\Rightarrow \boxed{V_{IH} = -0.325V}$$

③ D_A ON D_L off



$V_{out} = -V_{DC}$ because there is no voltage drop across R_L

$$\boxed{V_{OL} = -3V}$$

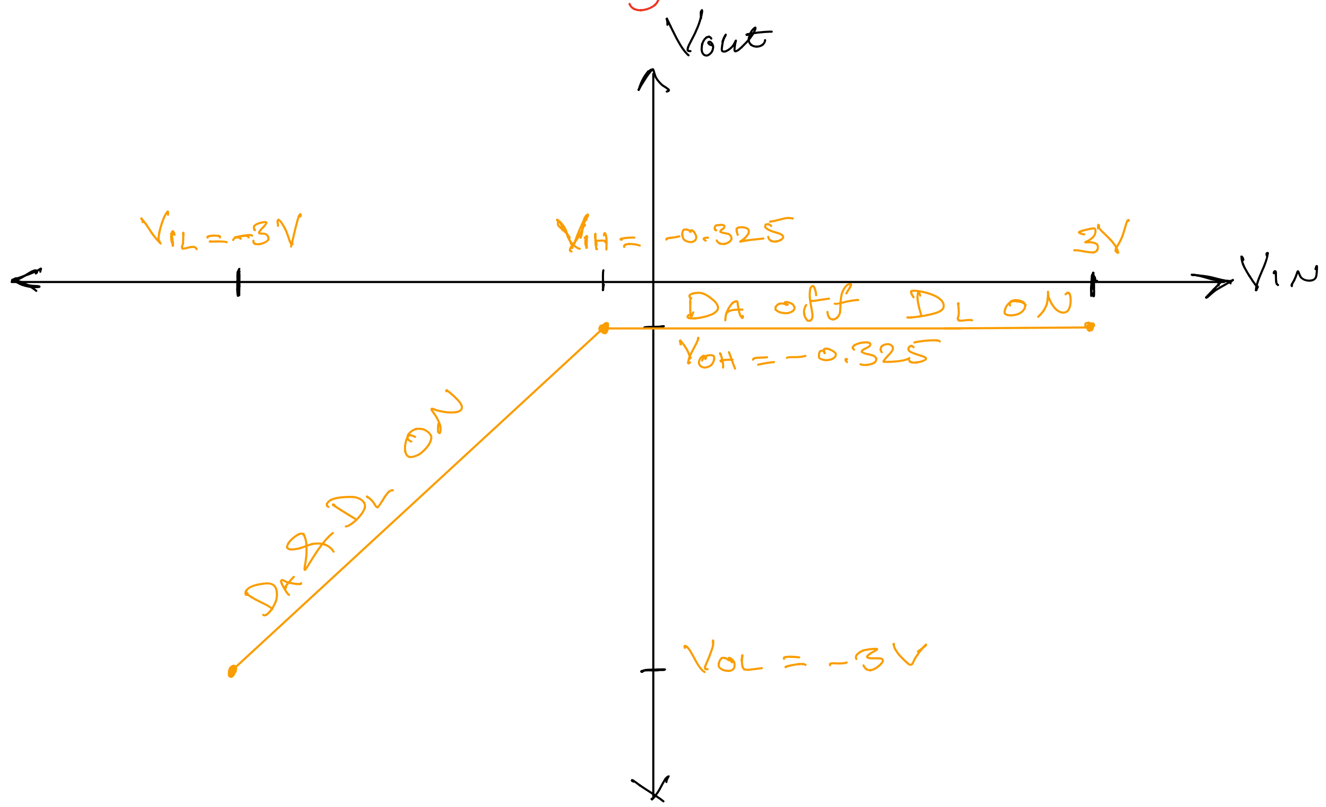
∴ at the edge $V_{out} = V_{in}$ is still valid & $-V_{DC} \leq V_{IN} \leq V_{DC}$

$$\Rightarrow \boxed{V_{IL} = -3V}$$

④ D_A off D_L off

If we assume D_A or D_L is off the condition to make the other diode to be off is not possible to be true therefore D_A & D_L is not possible to be off together.

* The VTC of the logic circuit.



ملاحظة: المسألة P 2.18 من مسائل Chapter 2 تحل بنفس الطريقة
مع إختلاف النتائج

م. الهمام الشريفي

Question 3: [2 Marks]

A. Determine the maximum number of inputs that an RTL NAND gate can have if the BJTs are designed to have $V_{BE}(FA) =$ 0.65V, $V_{BE}(SAT) =$ 0.75V, and $V_{CE}(SAT) =$ 0.15V

*If you read the question carfully you will understand the the required is to calculate Fan-in not Fan-out

*For Multi-Input RTL NAND Gate. the number of inputs are limited by

$$n < \frac{V_{BE}(FA)}{V_{CE}(sat)}$$

$$n < \frac{0.65}{0.15} = 4.33$$

$$n < 4.33$$

$$\Longrightarrow \boxed{n = 4}$$

Note In the question $V_{BE}(sat)$ is given but not required for the solution, so it might be a trick to examing your understanding of the subject.

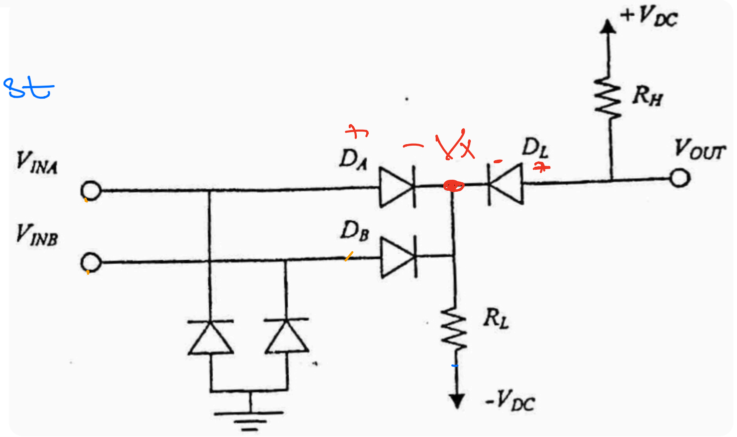
Question 2: [5 Marks]

Sketch the VTC for the diode level-shifting circuit shown below over the range,

a) $0 \leq V_{INA} \leq V_{DC}$ and $V_{INB} = 0$

b) $0 \leq V_{INA} \leq V_{DC}$ and $V_{INB} = V_{DC}/3$

Let $V_{DC} = 8V$, $R_H = R_L = 2K\Omega$, and $V_D(ON) = 0.7V$



For D_A or D_B to be ON we must make sure $V_{IN} \geq V_x + V_D(ON)$

We should find V_x for D_A & D_B are off

$$V_x = IR_L - V_{DC}$$

$$I = \frac{2V_{DC} - V_{D(ON)}}{R_H + R_L} = \frac{16 - 0.7}{4k} = 3.825\,mA$$

$$V_x = 3.825m \times 2k - 8 = -0.35$$

$$V_x + V_D(ON) = 0.35$$

For D_A or D_B to be ON we must make sure $V_{IN} \geq 0.35$ V

a) $0 \leq V_{INA} \leq V_{DC}$ & $V_{INB} = 0$

$V_{INB} = 0 \Rightarrow D_B$ is always off

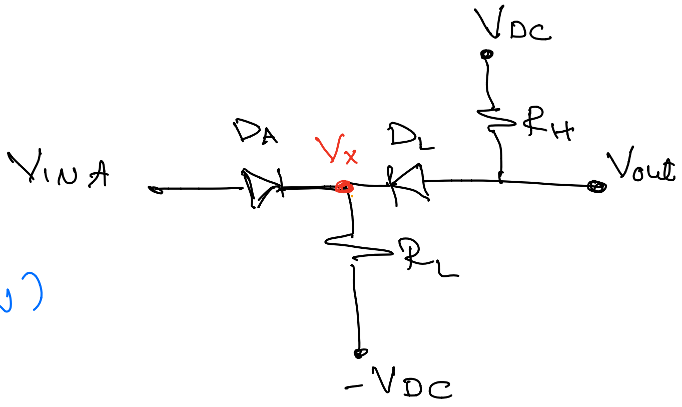
① D_A ON D_L ON

$$V_{out} = V_x + V_{D(ON)}$$

$$V_x = V_{IN} - V_{D(ON)}$$

$$V_{out} = V_{IN} - V_{D(ON)} + V_D(ON)$$

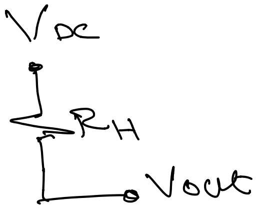
$$\boxed{V_{out} = V_{IN}}$$



② D_A ON D_L off

$$V_{out} = V_{DC} = V_{OH}$$

$$\boxed{V_{OH} = 8V}$$



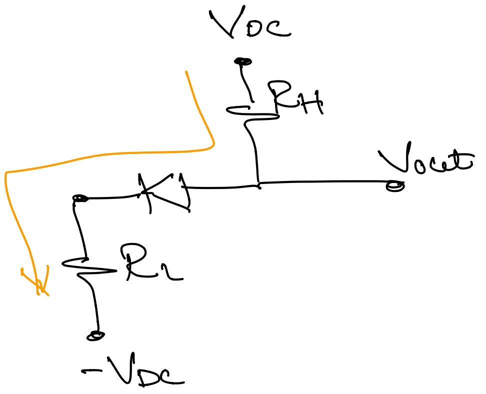
at the edge. $\boxed{V_{IH} = 8V}$

③ D_A off D_L ON

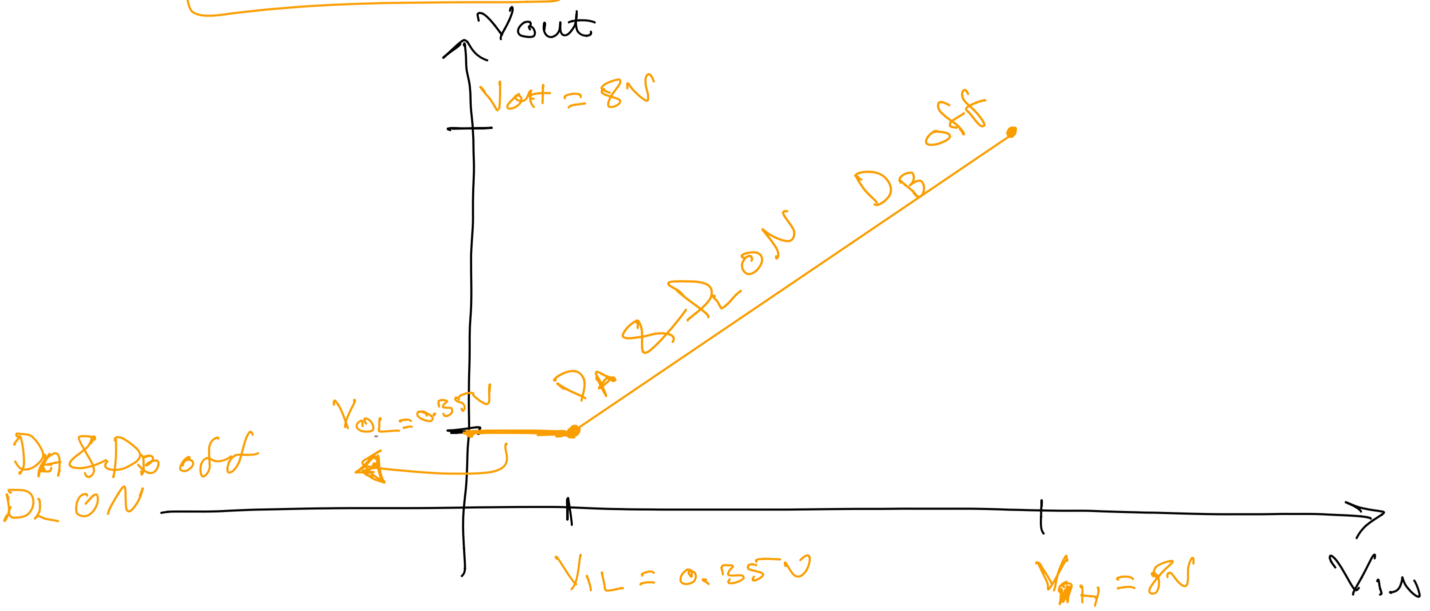
$V_{out} = V_{DC} - IR_H = V_{OL}$

$= 8 - 3.825m \times 2K = 0.35V$

$\boxed{V_{OL} = 0.35V}$



at edge $\boxed{V_{IL} = 0.35V}$



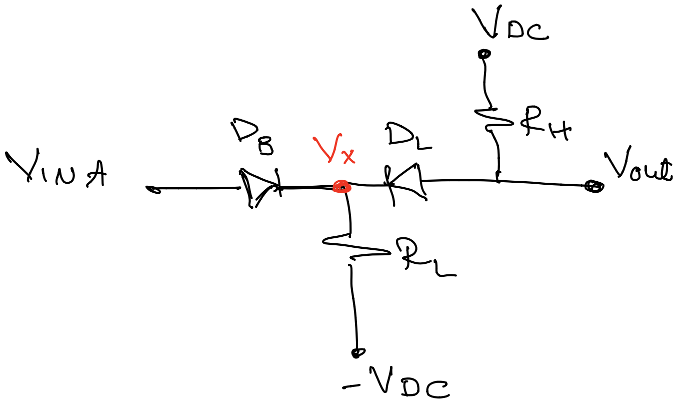
b) $0 \le V_{INA} \le V_{DC}$ & $V_{INB} = \frac{V_{DC}}{3} = 2.67V$

$V_{INB} = 2.67V \Rightarrow D_B$ is always ON

① D_L ON

from part (a)

$\boxed{V_{out} = V_{IN}}$

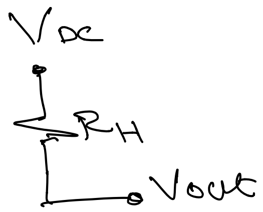


∴ D_B is always ON &

$V_{INB} = 2.67V$

$\Rightarrow \boxed{V_{out} \ge 2.67V}$

② D_L (off)



$V_{out} = V_{DC} = V_{OH}$

$\boxed{V_{OH} = 8V}$

at edge $\boxed{V_{IH} = 8V}$